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(54) Title of the Invention: Stage System, Exposure Apparatus, and Device Manufacturing Method

(57) Abstract

[Problems to Be Solved]

To realize highly efficient stage drive.

[Means to Solve the Problem]

When a coarse stage 34 is accelerated (and decelerated) by a linear motor 69, by applying a force in the acceleration (deceleration) direction from gas flow system 73 to fine stage 32, the reaction force by the coarse stage drive that acts on the fine stage is suppressed. By doing this, even if the kind of large force like that of conventional voice coil motors is not generated by the voice coil motors 71A to 71C for driving the fine stage, it is possible to maintain a specified positional relationship between both stages. Specifically, it is acceptable for the voice coil motor to generate only enough force to drive the fine stage slightly, so compared to conventional voice coil motors, etc., the required force is very small. Therefore, even with high acceleration of the coarse stage, it is possible for the voice coil motor to be more compact, and thus to make the overall stage small and lighter, and thereby efficient stage driving becomes possible.

[Claims]

[Claim 1]

A stage system comprising a first stage that can move in a first axial direction along a designated motion plane, a first drive system that drives said first stage in said first axial direction, a second drive system, a part of which is connected to said first stage, that drives a second stage on which is placed an object at least in said first axial direction, and a force generating system that generates force along said first axial direction on said second stage during at least one of the acceleration time and the deceleration time of said first stage.

[Claim 2]

The stage system of claim 1 which has a drive control system that drives said second stage using said second drive system and said force generating system together during the time that said first stage is being moved.

[Claim 3]

The stage system of claim 1 or 2 wherein said force generating system has the force point of application at the center of gravity of said second stage.

[Claim 4]

The stage system of any one of claims 1 through 3 wherein said force generating system has a first member that is connected to said second stage and a pair of second members that are connected to said first stage and placed divided by a designated gap in said first axial direction.

[Claim 5]

The stage system of any one of claims 1 through 4 wherein said second stage is positioned with an offset in relation to the direction of the motion of said first stage at the time of the start of acceleration of said first stage.

[Claim 6]

The stage system of claim 4 or 5 wherein one of said first member and said pair of second members has a gas jet mechanism that ejects pressurized gas on the facing surface of the other member.

[Claim 7]

The stage system of claim 4 or 5 wherein one of said first member and said pair of second members is an electromagnetic unit that has an electromagnet, and the other is a magnetic body that has a magnetic body that is attracted by the magnetic attraction force generated by said electromagnetic unit.

[Claim 8]

Exposure apparatus that synchronously moves a mask and substrate to transfer the pattern of said mask onto said substrate, wherein the exposure apparatus comprises the stage system of any one of claims 1 through 7 for which as said object, one of said mask and said substrate is placed on said second stage, a third stage on which is placed the other of said mask and substrate, and a control system that controls said stage system and said third stage

so that when transferring said pattern, said mask and said substrate are parallel and move in sequence in relation to said first axial direction from an acceleration state, to a constant velocity synchronous motion state, and to a deceleration state.

[Claim 9]

The exposure apparatus of claim 8 further comprising a position measuring system that measures the position of said first axial direction of said second stage, wherein said control system changes the weight of the force generation of said force generating system and the force generation of said first axial direction of said second drive system based on the output of said position measuring system and the control target values.

[Claim 10]

The exposure apparatus of claim 8 further comprising a gap measuring sensor that measures the gap between said first stage and said second stage, wherein said control system changes the weight of the force generation of said force generating system and the force generation of said first axial direction of said second drive system based on the output of said gap measuring sensor and the control target values.

[Claim 11]

A device manufacturing method that includes a lithography process, wherein the device manufacturing method performs exposure at said lithography process using the exposure apparatus noted in any one of claims 8 through 10.

Detailed Description of the Invention

[0001]

Technical Field of the Invention

The present invention relates to a stage system and exposure apparatus as well as a device manufacturing method, and more specifically relates to a stage system as well as exposure apparatus equipped with said stage system that is suitable to be used in scanning type exposure apparatus where a mask pattern is printed onto a substrate, and relates to a device manufacturing method that uses said exposure apparatus.

[0002]

Prior Art

In the lithography process where a semiconductor device or liquid crystal display device is manufactured, with a recent changes towards higher integration of semiconductor devices and larger size in a substrate such as a wafer and a reticle (hereinafter collectively called "reticle"), a scanning type exposure tool such as step-and-scan method scanning type exposure apparatus (what is known as scanning stepper), where a reticle pattern is consecutively printed onto a substrate via a projection optical unit while a reticle and a wafer are moving in synchronization along a prescribed scanning direction, is about to become the main stream.

[0003]

In scanning type exposure apparatus, in addition to a stage system on the substrate side for driving a reticle, a stage system is required on the reticle side as well. In recent scanning type exposure apparatus, a reticle stage system having a coarse-fine motion structure that has a reticle coarse stage that is driven in the scanning direction within a prescribed stroke by a linear motor and a reticle fine stage that is driven by a very small amount in the scanning direction, non-scanning direction and yawing direction relative to said reticle coarse stage by a voice coil motor, etc. is relatively more commonly used.

[0004]

Problems the Invention Attempts to Solve

Recently, the requirement for semiconductor exposure apparatus to increase a throughput is becoming increasingly harder, and in order to accommodate it, a reticle stage and a substrate stage need to achieve even higher acceleration.

[0005]

Therefore, when a reticle fine stage is driven relative to a reticle coarse stage using the aforementioned voice coil motor, the voice coil motor needs to generate a force that can absorb the reaction force that acts on the reticle fine stage during high acceleration (including deceleration) of the reticle coarse stage. For this reason, the size of the voice coil motor had to increase, and the weight of the voice coil motor itself had to increase, which inevitably lead to the increase in the weight of the reticle fine stage and the overall weight of the reticle stage. As the result, a power consumption of a linear motor for driving

a reticle stage (as a whole including a reticle coarse stage and voice coil motor) has become so big that it is about to become unacceptable.

[0006]

From the viewpoint of reducing the weight, a control method where a reticle fine stage is controlled using a mechanism comprising magnetic members such as an electromagnet and iron plate has been proposed, but a control stroke is small, and it is difficult to control it.

[0007]

The present invention is conceived in view of such inconveniences that prior arts have, and its first purpose is to provide a stage system that can simultaneously achieve reductions in size and weight as well as a reduction in power consumption.

[0008]

The second purpose of the present invention is to provide exposure apparatus that can improve the throughput during exposure.

[0009]

The third purpose of the present invention is to provide a device manufacturing method that can improve the productivity in manufacturing highly integrated micro devices where fine patterns are formed.

[0010]

Means to Solve the Problem

The invention described in Claim 1 is a stage system equipped with first stage 34 movable in the first axial direction along a designated motion plane, a first drive system 69 that drives said first stage in said first axial direction, a second drive system 71A ~ 71C, a part of which is connected to said first stage, that drives a second stage on which an object R is placed at least in said first axial direction, and a force generating system 73 and 73' that generates force along said first axial direction to said second stage during at least either of acceleration time or the deceleration time of said first stage.

[0011]

According to this, the first stage can be driven in the first axial direction along a designated motion plane by the first drive system, and the second stage on which an object is placed can be driven in at least the first axial direction by the second drive system, a part of which is connected to the first stage. Furthermore, it is also equipped with a force generating system that generates a force along the first axial direction to the second stage during at least either of the acceleration time or deceleration time of the first stage. For this reason, during the acceleration (and deceleration) of the first stage by the first drive system, the reaction force by the drive of the first stage acts on the second stage, but by generating a force along said first axial direction that suppresses the reaction force relative to the second stage by a force generating system, the second stage and the first stage can maintain a designated positional relationship. For this reason, the second drive system is not required to generate a force large enough to control the action of the reaction force like a conventional voice coil motor, and only a force for driving the second stage slightly in the first axial direction from a designated positional relationship is required. Therefore, compared to a conventional voice coil motor, the force required for the second drive system is small, and therefore even when the first stage is highly accelerated to drive an object at high acceleration, the size of the second drive system can be compact, and thus an overall stage can be reduced in its size and weight, thereby reducing the power consumption of the first drive system.

[0012]

In this case, as in the stage system described in Claim 2, it can be equipped with a drive control system 99 for driving said second stage by using said second drive system and said force generating system together while said first stage is moved.

[0013]

Furthermore, in each stage system described in the above-mentioned Claims 1 and 2, as in the stage system described in Claim 3, said force-generating system can set the point of application of the force at the center of gravity of said second stage.

[0014]

In each stage system described in the above mentioned Claims 1 through 3, as in the stage system described in Claim 4, said force generating system has a first member 81 & 81'

connected to said second stage and a pair of the second members 79A, 79B, 79A', 79B' arranged in said first axial direction with a predetermined space in between, and can generate said force by said first member and one of said pair of second members.

[0015]

In this case, as in the stage system described in Claim 5, said second stage is positioned with an offset at the start of the acceleration of said first stage in relation to the direction of the motion of said first stage.

[0016]

In each stage system described in the above mentioned Claim 4 and 5, various mechanisms can be employed as a force generating system, but as in the stage system described in Claim 6, said first member and one of said pair of second members can have a gas jet mechanism 79A & 79B which emits a jet of a pressurized gas to the surface facing the other member, or as in the stage system described in Claim 7, said first member and one of said pair of second members can be an electromagnet unit 75A' having electromagnets 79A and 79B' and the other can be a magnetic body unit 75B' having a magnetic body 81' that is attracted by a magnetic attractive force generated by said electromagnetic unit.

[0017]

The invention described in Claim 8 is an exposure apparatus where mask R and substrate W1, W2 are moved in synchronization to print said mask's pattern onto said substrate, and is characterized by being equipped with the stage system described in any of Claims 1 through 7 where either of said mask or said substrate is mounted on said second stage as said object, a third stage WST1, WST2 on which the other of said mask and substrate is mounted, a control system that controls said stage system and said third stage so that said mask and said substrate move in parallel in sequence from an acceleration state to constant velocity synchronous motion state to deceleration state in relation to said first axial direction.

[0018]

According to this, when printing mask's pattern onto a substrate, the stage system described in any of Claims 1 through 7 where either of a mask or substrate is mounted as an object on

the second stage and the third stage whereon the other of a mask or substrate is mounted are controlled by the control system so that a mask and substrate move in parallel with respect to the first axial direction from an acceleration state to constant velocity synchronous motion state to deceleration state in sequence. Thus, mask's pattern can be printed onto a substrate by a scanning exposure method. Here, in each stage system described in Claims 1 through 7, even when an object mounted on the second stage (either one of mask or substrate) is driven at high acceleration via the first stage, the second drive system can be compact, and thus the overall stage system can be reduced in its size and weight, thereby reducing the power consumption of the first drive system. Accordingly, because high acceleration of first stage can be achieved reasonably, a throughput can be improved, thanks to a reduction in a scanning exposure time. Furthermore, an improvement in the controllability of the position of an object can be expected, thanks to the reduction in size of the overall stage system, and as the result, an improvement in the exposure accuracy can be expected by an improvement in positioning accuracy of a mask and substrate.

[0019]

In this case, as in the exposure apparatus described in Claim 9, it is acceptable if it is further equipped with a position measurement system $66X$, $66Y_1$, $66Y_2$ that measures the position of said second stage in said first axial direction, and if said control system changes the weighting of the force generated by said force generating system and the force in said first axial direction generated by said second drive system based on an output from said position measuring system and control target value. Or, as in the exposure apparatus described in Claim 10, it is also acceptable if it is further equipped with a gap measuring sensor that measures the gap between said first stage and said second stage, and if said control system changes the weighting of the force generated by said force generating system and the force generated by said drive system in said first axial direction based on an output from said gap measurement sensor and control target value.

[0020]

The invention described in Claim 11 is a device manufacturing method that includes a lithography process and is characterized in that exposure is performed using the exposure apparatus described in any of Claims 8 through 10.

[0021]

[Embodiments of Invention] <<First Embodiment>>

Below, the first embodiment of the present invention will be explained in accordance with the Figure 1 through Figure 7. Figure 1 is a schematic and partial cross section of a structure of exposure apparatus 10 related to the first embodiment.

[0022]

Exposure apparatus 10 is a scan type exposure apparatus using a step and scan method, that is so-called scanning stepper that, while synchronously moving reticle R as a mask (object) and wafer W1 or W2 as a substrate in the one dimensional direction (here, it is the Y-axis direction that is the horizontal direction within the paper surface in Figure 1), transfers the circuit pattern formed on reticle R onto each shot range on wafer W1 (or W2) via projection optical unit PL.

[0023]

Exposure apparatus 10 is equipped with light source 11 for exposure (hereinafter simply referred to as "light source") disposed on floor surface F in a clean room, exposure apparatus main body 10A disposed on the negative side of Y-axis direction (-Y side) of said light source 11, routing optical unit connecting light source 11 and illumination optical unit IOP constituting exposure apparatus main body 10A, loader chamber 57 disposed next to said exposure apparatus main body 10A on the -Y side, and wafer loader chamber 61 (shown by the virtual line in Figure 1) connected to loader chamber 57 and disposed on the +X side (front side of the paper surface in Figure 1) of exposure apparatus main body 10A and so forth. Here, inside the routing optical unit, an optical unit for adjusting the optical axis called beam matching unit (BMU) is housed, so the routing optical unit is hereinafter referred to as "routing optical unit BMU."

[0024]

As the aforementioned light source, a pulse laser light source that outputs pulse ultraviolet radiation, for example, such as a KrF excimer laser (wavelength: 248nm), an ArF excimer laser (wavelength: 193nm) or an F2 laser (wavelength: 157 nm) is used. Connected to this light source 11 is light source control system 107 (not shown in Figure 1; see Figure 5) and based on the command from main control system 99 (not shown in Figure 1; see Figure 5),

the control of oscillation central wavelength of pulse ultraviolet radiation emitted from light source 11, the trigger control of pulse oscillation, the control of gas inside the laser chamber, etc. are performed by light source control system 107.

[0025]

The aforementioned routing optical unit BMU in this embodiment is disposed on the floor as clearly evident in Figure 1, however, it is also possible to dispose the major part of it under floor surface F.

[0026]

Loader chamber 57 is equipped with chassis 157, a wafer transfer part, not illustrated, installed at the bottom half of inside said chassis 157 and a reticle loader unit, not illustrated, installed at the upper half of inside chassis 157.

[0027]

At the aforementioned wafer transfer part placed inside chassis 157, a wafer is transferred to and from a wafer loader, not illustrated, placed inside the aforementioned wafer loader chamber 61. In addition, the wafer loader transfers a wafer to and from wafer stage WST1 or WST2, as will hereinafter be described, placed inside exposure apparatus main body 10A.

[0028]

On the other hand, the aforementioned reticle loader unit placed inside chassis 157 performs reticle loading and unloading to/from reticle stage RST via a reticle rotation transfer part, not illustrated, installed between loader chamber 57 and reticle stage RST.

[0029]

At the lower end of loader chamber 57 on the -Y side (opposite side of wafer loader chamber 61), interface part 31 is installed. Inside this interface part 31, a wafer transfer unit is housed and it transfers a wafer between a coater/developer (C/D), not illustrated, and the aforementioned wafer transfer part placed inside loader chamber 57.

[0030]

Exposure apparatus main body 10A is equipped with illumination optical unit IOP that irradiates reticle R by illumination light from light source 11, reticle stage RST holding

reticle R, projection optical unit PL that projects illumination light IL exited from reticle R onto wafer W1 or W2, wafer stage WST1 or WST2 as the third stage holding each wafer W1 or W2, respectively, and main body column BD that holds projection optical unit PL, etc. while movably respectively supporting reticle stage RST and wafer stage WST1 or WST2.

[0031]

The aforementioned illumination optical unit IOP is equipped with first illumination unit 44 that is extending in the vertical direction (Z-axis direction) and placed on the +Y side and at the end of the upper surface of base plate BP that is installed on floor surface F, and second illumination unit 46 disposed almost horizontally above said first illumination unit 44.

[0032]

The aforementioned first illumination unit 44 is equipped with first illumination housing 160, and a first part illumination optical unit comprised of a beam shaping optical unit disposed inside thereof with a predetermined position relationship, an optical integrator (uniformizer or homogenizer) for uniform illumination intensity distribution, a light quantity monitor, a variable aperture stop and a relay lens unit and so forth, (none of them illustrated). A light exiting surface of this first part illumination optical unit is roughly conjugate with the pattern surface of reticle R (hereinafter also referred to as "reticle surface" accordingly) and movable reticle blind 48 is disposed on this light exiting surface, and illumination intensity distribution compensation filter 50 for compensating illumination intensity distribution within the illuminating area is disposed on the surface (which is slightly defocused from the surface conjugate with the reticle surface) adjacent to the incidence surface side of said movable reticle blind 48.

[0033]

The aforementioned movable reticle blind 48 is controlled to open and close by blind drive system 105 (not shown in Figure 1; see Figure 5) based on the command from main control system 99 (see Figure 5) at the start and end of scan exposure to each shot range on a wafer, and by further limiting the illuminating area, it prevents an illumination light (exposure light) from irradiating an unwanted area other than the pattern area on which the circuit pattern is formed.

[0034]

The aforementioned second illumination unit 46 is equipped with second illumination unit housing 162 and a second part illumination optical unit comprised of a relay lens unit

disposed inside thereof with a predetermined position relationship, an optical path folding mirror and a condenser lens, etc. In addition, this second illumination unit 46 is supported by illumination unit support member 54 that is extending in the vertical direction and fixed to the upper surface of reticle stage base 30, as will hereinafter be described, constituting the aforementioned main body column BD.

[0035]

In this embodiment, as shown in Figure 1, fixed reticle blind 52 is fixed to the bottom surface of reticle alignment part 62 for performing alignment of reticle R. In other words, fixed reticle blind 52 is disposed on the upper surface close to reticle R, that is, the surface defocused from the reticle as much as a predetermined amount. In fixed reticle blind 52, an opening is formed for defining the illuminating area on the reticle surface to be a slit shape area that is elongate in the non-scan direction that is perpendicular to the scan direction. In addition, it is also possible to dispose fixed reticle blind 52 at places adjacent to the surface conjugate with the reticle surface, for example, the place adjacent to the installation surface of movable reticle blind 48.

[0036]

According to the illumination unit above, a laser beam emitted from light source 11 enters first illumination unit 44 via routing optical unit BMU. Then, this laser beam, with its cross section being shaped, becomes illumination light (exposure light) IL having almost uniform illumination intensity distribution, as it passes through the first part illumination optical unit inside first illumination unit 44, and passes through the opening of movable reticle blind 48. The illumination light IL passed through this movable reticle blind 48 enters second illumination unit 46, passes through the second part illumination optical unit inside said illumination unit 46 and irradiates fixed reticle blind 52 with almost uniform illumination intensity distribution. Then, this illumination light IL passed through the opening of fixed reticle blind 52 irradiates the illuminating area defined by the aforementioned fixed reticle blind 52 on reticle R with almost uniform illumination intensity.

[0037]

The aforementioned main body column BD is equipped with rectangular shape base plate BP horizontally mounted on floor surface F in the clean room, four first support posts 14 (but, two of the first support posts located at the front side of the paper surface are not shown in Figure 1) that are extending in the vertical direction as much as a predetermined length and placed at the four corners on the upper surface of said base plate BP, first

pedestal ST1 supported at the four points by these first support posts 14 via each of the first vibration isolation units 16 (but, two of the first vibration isolation units located at the front side of the paper surface are not shown in Figure 1), second pedestal ST2 supported at the four points by four second vibration isolation units 24 (but, two of the second vibration isolation units located at the front side of the paper surface are not shown in Figure 1) disposed on said first pedestal ST1, and third pedestal ST3 that is suspended and supported below the first pedestal ST1, etc. Out of these members above, frame caster FC is comprised of base plate BP and four first support posts 14.

[0038]

The aforementioned first pedestal ST1 is equipped with base frame 18 constituting its bottom plate part, two second support posts 20A, 20B that are extending in the vertical direction and fixed to places near the two corners located at the rear of the paper surface shown in Figure 1 on the upper surface of this base frame 18, and rectangular shape Y-axis stator support plate 60 supported almost horizontally by these two second support posts 20A, 20B.

[0039]

The aforementioned base frame 18 is comprised of a rectangular frame shape plate member having rectangular opening 18a formed at its center part, and supported almost horizontally by the aforementioned first vibration isolation units 16 at near the four corners of the bottom surface. Each of these first vibration isolation units 16 contains a mechanical type damper such as an air damper or hydraulic damper, which can endure heavy weight, disposed in series (or parallel) on top of first support posts 14 and an electromagnetic type damper composed of an electromagnetic actuator such as a voice coil motor, etc. Then, the tilt angle to the level of the upper surface of base frame 18 is detected by first displacement sensor 109 (not shown in Figure 1; see Figure 5), and based on the value detected by this displacement sensor 109, the electromagnetic type damper constituting four first vibration isolation units 16 is driven by main control system 99 (see Figure 5) such that the aforementioned tilt angle falls within the allowable range, and air pressure or hydraulic pressure for the mechanical type damper is controlled as needed. In this case, high frequency vibrations from the floor are attenuated by the mechanical type damper before being transmitted to exposure apparatus main body 10A, and residual low frequency vibrations are attenuated by the electromagnetic type damper. As the displacement sensor

above, for example, an electrical level or an optical tilt angle detector, etc. mounted on base frame 18 can be used.

[0040]

The aforementioned Y-axis stator support plate 60 is comprised of a rectangular plate member when viewed from the top, and a Y-axis stator, as will hereinafter be described, is disposed on its upper surface.

[0041]

The aforementioned second pedestal ST2 is equipped with projection optical unit support member 26 supported at the four points from underneath by four second vibration isolation units 24 disposed on the upper surface of base frame 18, four third support posts 28A, 28B, 28C, 28D (but, the third posts 28C and 28D positioned at the front side of the paper surface are not shown in Figure 1) that are extending in the vertical direction as much as a predetermined length and fixed at each position facing each second vibration isolation unit 24 placed on the upper surface of said projection optical unit support member 26, and reticle stage base 30 supported almost horizontally by these four third support posts 28A through 28D.

[0042]

The aforementioned projection optical unit support member 26 is comprised of a cylinder shape member having a flange part formed at the top edge. At the center of this projection optical unit support member 26, circular opening with steps 26a, according to a plane view (when viewed from the top), is formed communicating in the vertical direction (Z-axis direction). The aforementioned projection optical unit PL is inserted from top into this opening with steps 26a, and projection optical unit PL is supported by the projection optical unit support member 26 via flange FLG placed at slightly higher than the middle of the height direction.

[0043]

Furthermore, with projection optical unit support member 26, a plurality of through-holes is formed in the vertical direction (Z-axis direction) in addition to opening with steps 26a, and a plurality of lens barrels constituting various types of detection units is inserted into said through-holes. Meanwhile, these detection units will be described later.

[0044]

Each of the aforementioned second vibration isolation units 24 has a structure similar to the aforementioned first vibration isolation unit 16. (However, a load bearing capability is set

lower than that of first vibration isolation unit 16.) And, the tilt angle to the level of the upper surface of projection optical unit support member 26 or the upper surface of reticle stage base 30 is detected by second displacement sensor 111 (not shown in Figure 1; see Figure 5), and based on the value detected by this second displacement sensor 111, four second vibration isolation units 24 are controlled by main control system 99 (see Figure 5) such that the aforementioned tilt angle falls within an allowable range. As the displacement sensor above, for example, an electrical level or an optical tilt angle detector, etc mounted on projection optical unit support member 26 or reticle stage base 30 can be used.

[0045]

The aforementioned reticle stage base 30 is comprised of a rectangular plate member, according to the plane view (viewed from the top) as shown in Figure 3, and opening 30a (not shown in Figure 3; see Figure 1) for allowing illumination light IL to pass through is formed at the center part. Air guides 92A, 92B are installed on both ends in the X-axis direction of the upper surface of this reticle stage base 30, extending along the Y-axis direction. The upper surfaces of these air guides 92A, 92B are machined to be a guide surface having a very good flatness.

[0046]

The aforementioned reticle stage RST is levitated above the upper surface of reticle stage base 30 via air hydrostatic bearing 90, and equipped with reticle fine stage 32 as the second stage holding reticle R by means of vacuum clamping, etc. and reticle coarse stage 34 as the first stage that travels together with said reticle fine stage 32 by a predetermined stroke in the Y-axis direction which is the scan direction. In addition, in Figure 1, reticle fine stage 32 and reticle coarse stage 34 are shown as one reticle stage RST.

[0047]

Also, on reticle stage base 30, reticle Y-axis interferometers 66Y₁, 66Y₂ and reticle X-axis interferometer 66X are installed as a position measuring system for measuring the position of reticle fine stage 32, and the two dimensional position and rotation angle of reticle fine stage 32 are measured with high accuracy by these interferometers, and based on this measurement result, main control system 99 (see Figure 5) controls the position and velocity of reticle fine stage 32. In addition, in Figure 1, a total of three interferometers are collectively shown as reticle interferometer 66.

[0048]

Also, although not shown in Figure 3, each of reference mirrors that will be a reference for measurement is placed on the side surface of the lens barrel of projection optical unit PL, corresponding to each of reticle interferometers 66X, 66Y₁ and 66Y₂, respectively. These reference mirrors are collectively shown as reference mirror Mr in Figure 1. In addition, reticle interferometers will be further described later.

[0049]

Furthermore, disposed above Y-axis stator support plate 60 constituting the aforementioned main body column BD is, as shown in Figure 3, Y-axis stator 74 that is a stator of the linear motor for driving reticle coarse stage 34 in the Y-axis direction and that also functions as a counter mass that moves in the opposite direction from reticle coarse stage 34 along the Y-axis direction in order to cancel the reaction force generated during driving. In addition, reticle stage RST and the configuration of each part around this vicinity will be further described later.

[0050]

Back to Figure 1, as the aforementioned projection optical unit PL, a reduction unit having a reduction magnification of 1/4 (or 1/5) that is telecentric both on the object plane side (reticle side) and the image plane side (wafer side) is used. Because of this, when an illumination light (ultraviolet pulse light) IL from illumination optical unit I OP irradiates reticle R, an image formation light flux from the region that is illuminated by the ultraviolet pulse light in the circuit pattern field formed on reticle R enters projection optical unit PL, and a partial inverted image of this circuit pattern is formed being confined to an elongate slit shape or rectangular shape (polygon) in the X-axis direction at the center of visual field on the image plane side of projection optical unit PL at every pulse irradiation of the ultraviolet pulse light. By doing this, the projected partial inverted image of the circuit pattern is reduced and transferred onto a resist layer on the upper surface of one of plural shot ranges on wafer W1 (or wafer W2) disposed on the imaging plane of projection optical unit PL.

[0051]

As the projection optical unit PL, if an ArF excimer laser light source is used as the light source, a dioptric system comprised of only dioptric elements (lens elements) is mainly used; however, if an F2 laser light source, etc. is used, for example, as disclosed in Unexamined Patent Publication 3-282527, so-called catadioptric system where dioptric elements and cataoptric elements (concave mirror, beam splitter and so forth) are combined

or a cataoptric system comprised of only cataoptric elements is mainly used. However, it is possible to use a diopttric system when an F2 laser light source is used,

[0052]

The aforementioned third pedestal ST3 has stage base SB disposed below projection optical unit PL keeping it almost parallel to base plate BP, and four base support members 42 (but, two base support members located at the front of the paper surface are not shown) that support said stage base SB being suspended from the bottom surface of base frame 18.

Above the upper surface of stage base SB, the aforementioned wafer stage WST1 or WST2 is levitated via non-contact bearings, not illustrated, such as air hydrostatic bearings.

[0053]

Wafer stage WST1 or WST2 is, respectively, driven by wafer stage drive unit 70 (see Figure 5) that is comprised of, for example, a linear motor and so forth, and continuously moves in the Y-axis direction as well as moving in steps in the X-axis and Y-axis directions.

[0054]

Furthermore, inside each of wafer stages WST1, WST2, a table (not illustrated) is incorporated for moving wafer W1, W2 with micro motion in three degrees of freedom directions, that is, the Z-axis direction, the θ_x direction (rotation direction about the X-axis) and the θ_y direction (rotation direction about the Y-axis) in order to perform leveling and focusing of wafer W1, W2, respectively. Also, near wafer stage WST1, WST2, a counter mass mechanism (not illustrated) is installed to cancel the reaction force generated when each stage is driven.

[0055]

In exposure apparatus main body 10A of this embodiment, under illumination light IL, the pattern image within the illuminating area of reticle R is projected with a projection magnification β (β is a reduction magnification of $1/4$ or $1/5$, etc.) via projection optical unit PL on a slit shape exposure area (which is conjugate to the aforementioned illumination area) of the resist coated surface of wafer W1 (or W2). Under this condition, by synchronously moving reticle R and wafer W1 (or W2) in a predetermined scan direction (Y-axis direction), the pattern on reticle R is transferred onto one of shot ranges on wafer W1 (or W2).

[0056]

Next, using Figure 2 showing an enlarged view of the neighborhood of projection optical unit support member 26 in Figure 1, various types of sensors located near wafer stages WST1, WST2 are described.

[0057]

As shown in this Figure 2, lens barrel 172a constituting alignment unit ALG1 is inserted into through-hole 166a formed all the way through projection optical unit support member 26 in the vertical direction, and at the position corresponding to lens barrel 172a on the upper surface of projection optical unit support member 26, sensor head 174a constituting alignment unit ALG1 is disposed. Also, lens barrel 172b constituting alignment unit ALG2 is inserted into through-hole 166b formed on the opposite side of through-hole 166a in relation to projection optical unit PL, and at the position corresponding to lens barrel 172b on the upper surface of projection optical unit support member 26, sensor head 174b constituting alignment unit ALG2 is disposed.

[0058]

At the position of 45° diagonal to the X-axis and Y-axis from the center of projection optical unit PL around projection optical unit PL, a multipoint focus position detection unit that is one of oblique incidence type focus detection units (focus detection unit) for detecting the intra-exposure area on the surface of wafer W1 (or W2) and its neighborhood area in the Z-axis direction (optical axis AX direction) is provided. This multipoint focus position detection unit is comprised of irradiation optical unit 160a which consists of sensor head 41 and lens barrel 43 and is equipped with an optical fiber flux, a pattern formation plate, a mirror, a lens, etc. (none of them illustrated) inside thereof, and light receiving optical unit 160b (but only the lens barrel part of light receiving optical unit 160b is illustrated) equipped with a rotation direction vibration plate, a slit plate for receiving a light, a lens, a light receiver having many photosensors, etc. (non of them illustrated) inside thereof.

[0059]

At these multipoint focus position detection units (160a, 160b), a detection beam having a low photosensitivity to photoresist on wafer W1 (or W2) as well as a relatively wide wavelength band is irradiated diagonally from irradiation optical unit 160a to wafer W1 (or W2), and a reflected light of this detection beam from wafer W1 (or W2) is received by light receiving optical unit 160b. The light (image) received here is synchronously detected with rotation vibration frequency signals by signal processing system 103 (not shown in

Figure 1; see Figure 5). And, a lot of focus signals obtained after synchronized detection by this signal processing system 103 are supplied to main control system 99 shown in Figure 5.

[0060]

Also, on the side wall of both sides in the Y-axis direction at the lower half of projection optical unit support member 26, wafer Y-axis interferometers 80, 82 are mounted. In addition, on the side wall in the - X direction at the lower half of projection optical unit support member 26, wafer X-axis interferometer 84 (not shown in Figure 2; see Figure 5) for detecting the position of wafer stage WST1, WST2 in the X-axis direction is mounted. With these interferometers 80, 82 and 84, a laser beam generated at laser head 144 disposed on the upper surface of projection optical unit support member 26 is emitted toward wafer stage WST1, WST2 via a relay optical unit, not illustrated, that is comprised of a beam splitter, a mirror and so forth and mounted inside projection optical unit support member 26.

[0061]

Also, prealignment mechanisms 63A, 63B are disposed above the upper surface of stage base SB. These prealignment mechanisms 63A, 63B are for detecting a wafer center position shift as well as a rotation shift and for positioning a wafer.

[0062]

Furthermore, at the almost middle part in the height direction of base support member 42 suspending and supporting stage base SB, downflow unit 65 that blows a gas at an almost constant temperature from above to below is mounted. With this downflow unit 65, effects due to the heat in the optical path of the interferometer beam from wafer Y-axis interferometers 80, 82 as well as wafer X-axis interferometer 84 (see Figure 5) are reduced by the gas (air) coming out of downflow unit 65, making it possible to effectively reduce measurement errors and so forth caused by air fluctuations (temperature fluctuations of the air) on the optical path of the interferometer beam.

[0063]

Figure 3 is a schematic perspective view showing the construction of reticle stage RST and its neighborhood. The reticle stage RST contains reticle fine stage 32 and reticle coarse stage 34 as described above, and said reticle coarse stage 34 is driven in the Y-axis direction by Y-axis linear motor 69 as the first drive system.

[0064]

The aforementioned Y-axis linear motor 69 is equipped with Y-axis stator 74 mounted above Y-axis stator support plate 60 and Y-axis mover 72 moving in the Y-axis direction along said Y-axis stator 74.

[0065]

The aforementioned Y-axis stator 74 has the shape of a rectangular block where the Y-axis direction is the longitudinal direction, and a plurality of armature coils (not illustrated) arranged at predetermined intervals along the Y-axis direction are disposed inside thereof. The mass of this Y-axis stator 74 is set several times heavier than the combined mass of reticle stage RST and Y-axis mover 72. In addition, to make the mass of Y-axis stator 74 heavier, it is also possible to construct a moving coil type Y-axis linear motor placing a plurality of permanent magnets instead of a plurality of armature coils on Y-axis stator 74.

[0066]

At the neighborhood of both ends in the longitudinal direction on the bottom surface of Y-axis stator 74, a pair of air hydrostatic bearings 76a, 76b are mounted. The bearing surfaces of these air hydrostatic bearings 76a, 76b face the guide surface (upper surface) of Y-axis stator support plate 60, and by blowing out a pressurized gas such as a pressurized air toward said guide surface, and balancing the static pressure of the pressurized gas and their combined own weights of Y-axis stator 74, Y-axis mover 72 and reticle coarse stage 34 and so forth, Y-axis stator 74 is levitated with a clearance of about several microns above the guide surface. In addition, it is also possible to obtain a higher stiffness by using a vacuum pre-loaded bearing using a pressurized gas and vacuum suction or a magnetic pre-loaded bearing using a pressurized gas and magnetic attraction as a hydrostatic bearing.

[0067]

Also, Y-axis stator 74 is held without having any contact while being inserted into frame 94A and frame 94B fixed at each end of the Y-axis direction on the upper surface of Y-axis stator support plate 60. In other words, an air hydrostatic bearing, not illustrated, such as an air bearing is mounted on each inner surface in the X-axis direction of frames 94A, 94B, and by balancing static pressure of pressurized gases spouting out of these air bearings toward each side surface in the X-axis direction of Y-axis stator 74, Y-axis stator 74 is held between frames 94A and 94B with a clearance of several microns in the X-axis direction. Furthermore, Y-axis stator 74 is held by air hydrostatic bearings 76a and 76b with respect to the Z-direction, without having any contact with a clearance of several microns, not only from the guide surface of Y-axis stator support plate 60 but also from frames 94A and 94B.

In this manner, Y-axis stator 74 is constrained in both directions of X-axis direction and Z-axis direction without having any contact. In addition, as the air hydrostatic bearing, not illustrated, it is also possible to use the aforementioned vacuum pre-load bearing or magnetic pre-load bearing.

[0068]

Also, at one end (+Y side end) in the Y-axis direction of Y-axis stator 74, top plate member 96A and bottom plate member 96B are fixed sandwiching Y-axis stator 74 from above and below, and also at the other end (- Y side end) in the Y-axis direction of Y-axis stator 74, upper unit retention member 98A and lower unit retention member 98B are fixed sandwiching Y-axis stator 74 from above and below. The upper unit retention member 98A is made of a thin member whose XZ cross section is the shape of a letter U, and armature unit 101B is implanted in the concave groove at its center. The armature unit 101B has armature coils arranged at predetermined intervals along the Y-axis direction inside thereof. The lower unit retention member 98B is also constructed in a similar manner as the upper unit retention member 98A, and a similar armature unit is implanted. Furthermore, magnetic pole unit 101A is placed at the position facing armature unit 101B of the aforementioned frame 94B. By these armature unit 101B and magnetic pole unit 101A, Y-axis position compensation mechanism 102A for driving Y-axis stator 74 in the Y-axis direction is constructed. Also, on the lower unit retention member 98B side, Y-axis position compensation mechanism 102B (not shown in Figure 3; see Figure 5) is constructed in a similar manner.

[0069]

In this case, it is set such that the combined mass of top plate member 96A and bottom plate member 96B at one end in the Y-axis direction of Y-axis stator 74 is equal to the combined mass of upper unit retention member 98B, armature unit 101A, lower unit retention member 98B and armature unit 101B at the other end. Therefore, gravity is applied to the center of gravity of Y-axis stator 74, making it easy to control the air hydrostatic bearings having the identical action located at the equal distance from the center of gravity.

[0070]

Like this, Y-axis stator 74 is constrained in the X-axis direction as well as Z-axis direction without any contact; however, it is not constrained in the Y-axis direction at all. For this reason, if reticle stage RST is driven in the Y-axis direction together with Y-axis mover 72

to be described later, the reaction force in the opposite direction from the driving direction of reticle stage RST is applied to Y-axis stator 74; however, in so doing, in response to that reaction force in the Y-axis direction, Y-axis stator 74 moves in the Y-axis direction that is the opposite direction from the driving direction of reticle stage RST. In this case, the law of conservation of momentum is established, and the reaction force applied to Y-axis stator 74 is almost perfectly absorbed. In addition, an offset load due to the shift of the center of gravity will not occur. Therefore, it is made possible to almost perfectly prevent vibrations due to the reaction force from being generated when reticle stage RST is driven.

[0071]

Also, in this embodiment, the current to be supplied to the armature unit for driving Y-axis position compensation mechanisms 102A, 102B in the Y-axis direction is controlled and Y-axis stator 74 is made to return to its original position in the Y-axis direction at an appropriate timing by main control system 99 in Figure 5 so that the travel amount of Y-axis stator 74 in the Y-axis direction due to the reaction force applied when reticle stage RST is driven does not deviate from the stroke range of Y-axis position compensation mechanisms 102A, 102B described above.

[0072]

The aforementioned Y-axis mover 72 is equipped with a magnetic member having a rectangular shape that is short in the X-axis direction and long in the Y-direction according to a plane view (when viewed from the top) and its XZ cross section has the shape of an inverted letter U (a letter U lying on its left side), and N-pole permanent magnets and S-pole permanent magnets being alternately disposed at predetermined intervals along the Y-axis direction on a pair of facing surfaces inside this magnetic member. In this case, the polarity of the magnets facing each other in the X-axis direction is set to be different, (in other words, a pair of facing magnets in the X-axis direction are an N-pole permanent magnet and an S-pole permanent magnet). Here, the N-pole permanent magnet and the S-pole permanent magnet refer to the permanent magnets in which each surface of the magnets facing Y-axis stator 74 is an N-pole face and an S-pole face, respectively.

[0073]

In other words, in the condition shown in Figure 3, Y-axis mover 72 is arranged to generate an alternate magnetic field at predetermined cycles along the X-axis direction in a gap with Y-axis stator 74, and with these Y-axis mover 72 and Y-axis stator 74, moving magnet type Y-axis linear motor 69 is constructed as the first drive system that drives the

aforementioned reticle coarse stage 34 within a predetermined stroke in the Y-axis direction. The current value (including the direction) to be supplied to the armature coils constituting Y-axis stator 74 of this Y-axis linear motor 69 is controlled by main control system 99 shown in Figure 5.

[0074]

The aforementioned reticle coarse stage 34 has an L shape according to a plane view (when viewed from the top) and is fixed to the side surface on the +X side of mover 72 of Y-axis linear motor 69 being cantilevered out above reticle stage base 30.

[0075]

The aforementioned reticle fine stage 32 comprises a rectangular shape member according to a plane view (when viewed from the top) and a rectangular opening (not illustrated) that becomes a path for illumination light IL is formed at its almost center part. On the upper surface side around this opening, a plurality (for example, four) of vacuum chucks, not illustrated, is placed, and reticle R is held by vacuum chucking by these vacuum chucks.

[0076]

Also, at the four corners of the bottom surface of reticle fine stage 32, air hydrostatic bearings 90 that are similar to the aforementioned air hydrostatic bearings 76a, 76b placed on the Y-axis stator 74 are placed, respectively, (but the air hydrostatic bearings at the rear side are not shown in Figure 3.) These air hydrostatic bearings 90 are placed at the positions facing guide surfaces (upper surfaces) of air guides 92A, 92B above reticle stage base 30, and by blowing out a pressurized gas (such as a pressurized air) toward said guide surface and balancing the static pressure of the pressurized gas and its own weight of reticle fine stage 32, reticle fine stage 32 is levitated with a clearance of about several microns above the guide surface. In addition, as an air hydrostatic bearing 90, it is also possible to use the aforementioned vacuum pre-load bearing or magnetic pre-load bearing.

[0077]

Furthermore, at the end of +X side of the upper surface of reticle fine stage 32, as shown in Figure 3, reticle X movable mirror 64X comprised of a planar mirror is fixed. A laser beam from the aforementioned reticle X-axis interferometer 66 is irradiated vertically on this X movable mirror 64X. Also, at the end of +Y side of the upper surface of reticle fine stage 32, a pair of corner cubes 64Y₁, 64Y₂ are fixed, and a laser beam from the aforementioned reticle Y-axis interferometers 66Y₁, 66Y₂ is irradiated on these corner cubes 64Y₁, 64Y₂, respectively. In addition, a laser beam from interferometers 66X, 66Y₁, and 66Y₂ is a split

beam of the laser beam generated at interferometer laser 68 fixed to the upper surface of reticle stage base 30.

[0078]

And, by reticle Y-axis interferometers 66Y₁, 66Y₂, the Y-axis direction position and θ_z rotation of reticle fine stage 32 are always detected with the resolution on the order of 0.5nm to 1nm, for example, with reference to the reference mirror, and by reticle X-axis interferometer 66X, the X-axis direction position of reticle fine stage 32 is always detected with the resolution on the order of 0.5nm to 1nm, for example, with reference to the reference mirror.

[0079]

In this case, as reticle Y-axis interferometers 66Y₁, 66Y₂, a pair of double path interferometers that detects the Y-axis direction position of corner cubes 64Y₁, 64Y₂ by having a laser beam incident on corner cubes 64Y₁, 64Y₂ and receiving a reflected light, respectively, is used; therefore, even if a θ_z rotation exists in reticle fine stage 32, it is possible to detect the Y-axis direction position of the incident position of each laser beam with good accuracy.

[0080]

Between reticle fine stage 32 and reticle coarse stage 34, non-contact mount system 115 (see Figure 5) for holding reticle fine stage 32 to reticle coarse stage 34 without any contact is placed. This non-contact mount system 115 is, in this embodiment, equipped with voice coil motors 71A, 71B, 71C as a second drive system and gas flow system 73 as a force generating system shown in Figure 3.

[0081]

At the voice coil motor 71B that is one of the aforementioned voice coil motors 71A to 71C, as shown by a cross section in Figure 4 (A), its stator 67A is fixed to reticle coarse stage 34 and its mover 67B is fixed to the side wall on the - Y side of reticle fine stage 32.

[0082]

The aforementioned stator 67A comprises a magnetic member and is equipped with yoke 95 whose YZ cross section has the shape of roughly a letter U (a letter U lying on its left side) and N-pole permanent magnet 59N and S-pole permanent magnet 59S arranged on a

pair of facing surfaces (facing surfaces of top and bottom) inside said yoke 95. These N-pole permanent magnet 59N and S-pole permanent magnet 59S are constructed with ordinary permanent magnets and set such that the poles of magnets facing each other are N-pole and S-pole, respectively. Also, the aforementioned mover 67B has the shape of an almost flat plate and is equipped with chassis 93 having a space inside thereof and armature coil 91 enclosed inside that internal space.

[0083]

In other words, in the condition where stator 67A and mover 67B are engaged as shown in Figure 4 (A), it is possible to generate force in the Y-axis direction by electromagnetic interaction (Lorentz force) between magnetic field in the Z-axis direction formed inside stator 67A and current in the X-direction flowing through armature coil 91 inside mover 67A, and this enables reticle fine stage 32 to be driven in micro motion in the Y-axis direction relative to reticle coarse stage 34.

[0084]

In addition, in this embodiment, the point of force application of voice coil motor 71B is set as the same height as the center of gravity of reticle fine stage 34. For this reason, a rotation moment that rotates reticle fine stage 32 in the θ_x direction (rotation direction about X-axis) will not be generated by the force of voice coil motor 71B.

[0085]

Other voice coil motors 71A, 71C are also constructed in the similar way voice coil motor 71B is constructed. In other words, by voice coil motor 71A, it is made such that reticle fine stage 32 can be driven in micro motion in the X-axis direction relative to reticle coarse stage 34 without generating a rotation moment that rotates it in the θ_y direction (rotation direction about Y-axis). Also, as in the case of voice coil motor 71B, by voice coil motor 71C, it is made possible to drive reticle fine stage 32 in micro motion in the Y-axis direction relative to reticle coarse stage 34 without generating a rotation moment that rotates it in the θ_x direction. Also, by differentiating the force generated by voice coil motors 71B, 71C, it is made possible to drive reticle fine stage 32 in micro motion in the rotation direction (θ_z direction) about Z-axis.

[0086]

The aforementioned gas flow system 73 is, as shown in Figure 3, equipped with gas flow fixed part 75A placed in the middle between each of stators of aforementioned voice coil motors 71B, 71C of reticle coarse stage 34 and gas flow moving part 75B connected to reticle fine stage 32.

[0087]

The aforementioned gas flow fixed part 75A is, in reality, as shown by a cross section in Figure 4 (B), equipped with hollow chassis 77 having the shape of a rectangular parallelepiped and gas jet mechanisms 79A, 79B as a pair of second members fixed to the both internal surfaces in the Y-axis direction of said chassis 77. Also, the aforementioned gas flow moving part 75B is equipped with arm member 83 having the shape of a letter U (see Figure 6 (A)) according to a plane view (viewed from the top) provided in a protruding manner at the surface in the - Y side of reticle fine stage 32 and plate shape member 81 as a first member fixed to the edge (- Y side edge) of arm member 83 disposed between a pair of gas jet mechanisms 79A, 79B. The arm member 83 is inserted into chassis 77 via two rectangular shape openings 101 (but, only one opening is illustrated in Figure 4 and the other opening is not illustrated) formed in chassis 77.

[0088]

To the surface on the - Y side as well as the surface on the + Y side of plate shape member 81, a pressurized gas (such as air, nitrogen or helium, etc.) is always or accordingly blown out of gas jet mechanisms 79A, 79B.

[0089]

Here, gas flow system 73 is set such that the point to which its generating force is applied on reticle fine stage 32 and the center of gravity of reticle fine stage 32 are identical in terms of the Z-axis direction position and the X-axis direction position. In this way, gas flow system 73 is structured to push the center of gravity of reticle fine stage 32, so a rotation moment in the θ_x direction as well as the θ_z direction in relation to reticle fine stage 32 will not be generated at all by the force applied from gas flow system 73.

[0090]

Next, the relationship of generating forces between voice coil motor 71B (and 71C) and gas flow system 73 is explained referring to Figures 4 (A) and 4 (B). In addition, Figure 4 (A) and Figure 4 (B) show the condition of voice coil motor 71B and gas flow system 73 when the relative position of reticle fine stage 32 and reticle coarse stage 34 is identical.

[0091]

On the gas flow system 73 side, plate shape member 81 is pushed back by the power that is proportional to the square of the distance of plate shape member 81 from gas jet mechanisms 79A, 79B, so plate shape member 81 is positioned at the distance nearly equal from gas jet mechanisms 79A, 79B as shown in Figure 4 (B), and in the case like this embodiment wherein an equal amount of gas is blown out of gas jet mechanisms 79A, 79B, either two forces applied to plate shape member 81 are balanced or the forces are both small, such that the generated force of gas flow system 73 does not virtually affect plate shape member 81.

[0092]

Here, the case (i) where reticle fine stage 32 moves to the left from the state (neutrality) of Figure 4 (A), Figure 4 (B) and the case (ii) where reticle fine stage 32 moves to the right from the state (neutrality) of Figure 4 (A), Figure 4 (B) will briefly be explained.

[0093]

In the case of (i), in gas flow system 73, plate shape member 81 shifts to the left from the state of Figure 4(B), so plate shape member 81 comes close to gas jet mechanism 79A. Therefore, to plate shape member 81, the force toward the right (+ Y side) is applied by the power of the gas blowing out of gas jet mechanism 79A. The force applied to plate shape member 81 from gas jet mechanisms 79A, 79B is inversely proportional to the square of the distance of plate shape member 81 from gas flowing mechanisms 79A, 79B. For this reason, the gas blowing out of gas jet mechanism 79B does not virtually affect plate shape member 81. On the other hand, the force toward the right by the power of the gas blowing out of gas jet mechanism 79A becomes the power that is inversely proportional to the square of the distance described above and pushes back plate shape member 81. In other

words, at the position where reticle fine stage 32 is moved to the left, voice coil motor 71B does not require a large force.

[0094]

In the case of (ii), since reticle fine stage 32 is positioned at the place farther right than Figure 4 (A), in voice coil motor 71B, mover 67B shifts to the right from the neutrality; therefore, the current flowing through permanent magnets 59N, 59S becomes smaller compared to the case in Figure 4 (A). Therefore, it is not possible to bring out as much the response as in the case of neutrality. On the other hand, in gas flow system 73, plate shape member 81 shifts to the right from the state of Figure 4 (B), so plate shape member 81 comes closer to gas jet mechanism 79B. Therefore, to plate shape member 81, the force toward the left (- Y side) is applied by the power of gas blowing out of gas jet mechanism 79B. At this time, due to the reason similar to what is described above, the gas blowing out of gas jet mechanism 79A does not virtually affect plate shape member 81. On the other hand, the force toward the left by the power of gas blowing out of gas jet mechanism 79B becomes the power whose magnitude is inversely proportional to the square of the distance described above and pushes back plate shape member 81. In other words, at the position where reticle fine stage 32 is moved to the right, voice coil motor 71B does not require a large force. Therefore, when plate shape member 81 is positioned at the left or right side, that is, when reticle coarse stage 34 moves from side to side at high acceleration, gas jet mechanisms 79A, 79B provide most of the force to move reticle fine stage 32 in synchronization so voice coil motor 71B does not require a large force.

[0095]

Next, processing in exposure apparatus main body 10A of this embodiment is explained.

[0096]

In this embodiment, while wafer stage WST1 is performing exposure right under projection optical unit PL, on the wafer stage WST2 side, wafer exchange and alignment are performed right under alignment unit ALG2. Similarly, while wafer stage WST2 is performing exposure right under projection optical unit PL, on the wafer stage WST1 side,

wafer exchange and alignment are performed right under alignment unit ALG1. In other words, at wafer stages WST1, WST2, a parallel processing is performed.

[0097]

In the aforementioned wafer exchange, by the wafer loader not illustrated inside wafer loader part 61, unloading of the already exposed wafer placed on wafer stage WST1 (or wafer stage WST2) as well as loading of a new wafer are performed.

[0098]

Also, during alignment operation, using alignment units ALG1, ALG2, wafer alignment such as an EGA (Enhanced Global Alignment) disclosed in Unexamined Patent Publication 61-44429 and so forth is executed. Upon completion of alignment such as this, a step and scan type exposure is performed as below.

[0099]

Below, exposure operation (step and scan exposure) of each wafer stage WST1, WST2 is explained referring to Figure 5 and other drawings accordingly.

[0100]

First, based on the alignment result, while monitoring measurement values of the aforementioned wafer Y-axis interferometers 80, 82, and wafer X-axis interferometer 84, main control system 99 controls the linear motor constituting wafer stage drive unit 70 and moves wafer stage WST1 (or WST2) to the scan start position (acceleration start position) for exposure of a first shot on wafer W1 (or W2).

[0101]

Next, at main control system 99, reticle R and wafer W1 (or W2), that is, reticle stage RST and wafer stage WST1 (or WST2) start a relative scanning in the Y-axis direction, and when both stages reach their respective target scanning speed and attain the state of synchronized constant velocity, a pattern field of reticle R is illuminated by an ultraviolet pulse light from illumination optical unit IOP and a scanning exposure begins. The relative scanning above is performed as main control system 99 controls the linear motor constituting Y-axis linear motor 69 as well as wafer stage drive unit 70, while monitoring

measured values of wafer interferometers 80 (or 82), 84 and reticle interferometers 66Y₁, 66Y₂ and 66X.

[0102]

At main control system 99, in particular at the time of scanning exposure described above, to maintain the travel velocity in the Y-axis direction of reticle stage RST and the travel velocity in Y-axis direction of wafer stage WST1 (or WST2) at a velocity ratio corresponding to the projection magnification (reduction of 1/4 or 1/5) of projection optical unit PL, reticle stage RST and wafer stage WST1 (or WST2) are synchronously controlled via Y-axis linear motor 69 and wafer stage drive unit 70.

[0103]

And a different field in the pattern field of reticle R is consecutively irradiated by an ultraviolet pulse light and by completing illumination to the entire surface of pattern field, scanning exposure of a first shot on wafer W1 (or W2) finishes. By doing this, the pattern of Reticle R is reduced and printed on to the first shot via projection optical unit PL.

[0104]

In addition, right before the start of scanning exposure and right after the end of exposure described above, movable reticle blind 48 is controlled by blind drive system 105 based on the command from main control system 99 and exposure of an unwanted part is prevented as in the case of a normal scanning stepper.

[0105]

As described above, when scanning exposure of a first shot is complete, wafer stage WST1 (or WST2) is moved in steps in the X- and Y-axis directions via wafer stage drive unit 70 to the scanning start position (acceleration start position) for exposure of a second shot by main control system 99.

[0106]

And, operation of each part is controlled in the same way as described above, and scanning exposure is performed to the second shot on wafer W1 (or W2) in the same way as described above by main control system 99.

[0107]

In this way, scanning exposure of a shot on wafer W1 (or W2) and stepping motion for the next shot exposure are repeated and the pattern on reticle R is printed in sequence on to the entire shots subject to exposure on a wafer.

[0108]

Next, a control method of reticle stage RST at the time of the scanning exposure described above is explained referring to Figure 6 (A) to Figure 6 (C) as well as Figure 7 (A) and Figure 7 (B). Figure 6 (A) to Figure 6 (C) show a frame format of voice coil motors 71B, 71C under various conditions and the state of gas flow system. Figure 7 (A) shows the change in acceleration of reticle coarse stage 34 over time. Also, Figure 7 (B) shows the change in velocity of reticle coarse stage 34 over time that corresponds to Figure 7 (A). In addition, in Figure 7 (A) and Figure 7 (B), range Acc means reticle coarse stage 34 is accelerating, range Uni means it is moving at a constant velocity and range Dec means it is decelerating.

[0109]

First, the case where reticle stage SRT is accelerating to the right (time_{t0} to t1 in Figure 7 (A) and Figure 7 (B)) is explained. Here, as the premise, in accelerating reticle stage RST, each mover has been driven to the left by a predetermined amount from the aforementioned state of neutrality by the current supplied to the movers of voice coil motors 71B, 71C by main control 99 (see Figure 5). In other words, at the time acceleration starts (time t₀ in Figure 7 (A) and Figure 7 (B)), reticle fine stage 32 is set to the condition of Figure 6 (A) where it is positioned with a given offset to the -Y side with respect to the Y-axis direction. Under this condition, acceleration of reticle coarse stage 34 starts as shown in Figure 7 (A).

[0110]

If reticle coarse stage 34 is accelerated to the right (+ Y side) in the condition where reticle fine stage 32 moved to the left (- Y side), a reaction force to the left will be further applied to reticle fine stage 32; however, an equal amount as well as a constant flow of gas is blown out of gas jet mechanisms 79A, 79B by main control system 99 at the same time acceleration starts, so the force due to the pressure of gas blowing out of gas jet mechanism 79A is applied to plate shape member 81 such that it does not move any farther to the left.

In other words, a gap wider than a predetermined gap is maintained between plate shape member 81 and gas jet mechanism 79A.

[0111]

Here, in this embodiment, in accelerating reticle coarse stage 34, rather than constantly maintaining the same acceleration, a sequence where it accelerates at the maximum acceleration set about twice as high as the average acceleration right after acceleration starts and at accelerations lower than the average acceleration right before time t_{11} when the constant velocity motion starts is employed as shown in Figure 7 (A).

[0112]

For this reason, during acceleration range Acc, once plate shape member 81 and gas jet mechanism 79A on the left side come closest to each other when reticle coarse stage 34 moves at the maximum acceleration right after acceleration starts, plate shape member 81 gradually moves away from gas jet mechanism 79A by a decrease in the reaction force applied to reticle fine stage 32 due to a decreased acceleration as well as a constant flow of gas blowing out of gas jet mechanism 79A.

[0113]

In this case, the stiffness of the gas is lowered by $1/y^2$ as the gap y between plate shape member 81 and gas jet mechanism 79A widens, and when the entire plate shape member 81 is positioned within the range sandwiched by the dashed line as shown in Figure 6 (A), almost no force of constraint by the gas remains; on the other hand, however, the gap between plate shape member 81 and gas jet mechanism 79A widens as described above, so voice coil motors 71B, 71C can be controlled with high response. In this way, during acceleration range Acc, it is possible to gradually switch the control of reticle fine stage 32 from gas flow system 73 to voice coil motors 71B, 71C.

[0114]

After that, in the case where reticle coarse stage 34 moves at an almost constant velocity (time t_{11} to t_{12} in Figure 7 (A), Figure 7 (B)), the entire plate shape member 81 is positioned within the range sandwiched by the dashed line as shown in Figure 6 (B), so it is possible to control reticle fine stage 32 with high response only by voice coil motors 71B, 71C.

Therefore, it is adapted to synchronize reticle R and wafer W1 (or W2) by voice coil motors 71B, 71C. Here, the force (reaction force) in the scanning direction is not applied to reticle fine stage 32 during the movement at a constant velocity, so not much force is required for voice coil motors 71B, 71C.

[0115]

Next, in decelerating reticle coarse stage 34 (time t_2 to t_3 in Figure 7 (A), Figure 7 (B)), deceleration starts from time t_2 shown in Figure 7 (A), Figure 7 (B) in the condition where the force of voice coil motors 71B, 71C is somewhat reduced in advance. In this deceleration, contrary to the time of acceleration described above, reticle coarse stage 34 moves at a deceleration lower than the average deceleration right after deceleration starts, and moves at a deceleration about twice as high as the average deceleration right before time t_3 when the velocity becomes 0. For this reason, the reaction force applied to reticle fine stage 32 becomes gradually larger during the period from deceleration start time t_2 to deceleration end time t_3 , so plate shape member 81 gradually comes closer to gas jet mechanism 79B on the right as shown in Figure 6 (C), and plate shape member 81 and gas jet mechanism 79B come closest to each other at time t_3 when the velocity becomes 0. In addition, also in this case, the force to the left is applied to plate shape member 81 by a constant flow of gas blowing out of gas jet mechanism 79B, so a gap wider than a predetermined gap is maintained between plate shape member 81 and gas jet mechanism 79B.

[0116]

In this way, at time t_3 when deceleration ends, reticle fine stage 32 is set to the condition of Figure 6 (C) where it is positioned with a given offset to the +Y side with respect to the Y-axis direction from the aforementioned state of neutrality, so it is possible to smoothly accelerate reticle stage RST to the left (-Y direction) from this condition.

[0117]

In the same way, reticle coarse stage 34 is moved in the manner of acceleration to the left, constant velocity, deceleration to the left, acceleration to the right and so forth.

[0118]

As evident from the explanation so far, in this embodiment, the stage system is comprised of reticle fine stage 32, reticle coarse stage 34, Y-axis linear motor 69, non-contact mount system 115 holding reticle fine stage 32 without having any contact in relation to reticle coarse stage 34 and main control system 99 as a control system for controlling these units. Also, in this embodiment, a drive control system for driving reticle fine stage 32 is constructed by using voice coil motor in combination with gas flow system 73, while moving reticle coarse stage 34 by main control system 99.

[0119]

As explained in detail above, according to the stage system of this embodiment, at the times reticle coarse stage 34 is accelerated or decelerated by Y-axis linear motor 69, the reaction force due to the driving of reticle coarse stage 34 acts on reticle fine stage 32 that is held without having any contact in relation to reticle coarse stage 34; however, the force in such direction to suppress the reaction force is generated by gas flow system 73 at the times coarse stage 34 is accelerated or decelerated, making it possible to maintain a predetermined relationship (that is, the condition of being held without having any contact) between reticle coarse stage 34 and reticle fine stage 32. For this reason, the power to suppress the action of reaction force is not required for voice coil motors 71A to 71C that drive reticle coarse [sic; should be "fine"?; translator] stage 32 in micro motion. Therefore, compared to the case where only voice coil motors 71A to 71C are used without using gas flow system 73, the force required for voice coil motors 71A to 71C is small. For this reason, even in the case where reticle coarse stage 34 is driven at high acceleration, it becomes possible to make voice coil motors 71A to 71C compact, making it possible to reduce the weight of voice coil motors and thereby the entire reticle stage.

[0120]

In this case, by controlling an increase in weight of voice coil motors as much as possible, an increase in weight of the entire reticle stage system 25 including voice coil motors is kept down, making it possible to maintain the electrical power to be consumed by Y-axis linear motor 69 that drives reticle coarse stage 34 as small as possible.

[0121]

Also, plate shape member 81 of gas flow system 73 is connected to reticle fine stage 32, and a pair of gas jet mechanisms 79A, 79B maintaining a predetermined gap in the Y-axis and sandwiching plate shape member 81 is connected to reticle coarse stage 34. In this case, it is constructed such that the force essentially acts on plate shape member 81 in the condition where plate shape member 81 comes within a predetermined distance from either one of gas jet mechanisms 79A, 79B, and the force essentially does not affect plate shape member 81 in the condition where plate shape member 81 moves away from both gas jet mechanisms 79A, 79B at the same time by greater than a predetermined distance. Therefore, only by using a simple method of changing the position relationship of plate shape member 81 and each gas jet mechanism, it is made possible to resist the reaction force applied to reticle fine stage 32 due to the driving of reticle coarse stage 34.

[0122]

In particular, because it is possible for voice coil motors 71B, 71C to drive reticle fine stage 32 in micro motion with high response in the condition where plate shape member 81 moves away from both gas jet mechanisms 79A, 79B at the same time by greater than a predetermined distance and where the force essentially does not affect plate shape member 81, it becomes possible to perform tracking control of the reticle fine stage with high response to move in synchronization with wafer stage WST1 (or WST2) during the synchronized constant velocity movement when there is no effect of the reaction force on reticle fine stage 32 due to the driving of reticle coarse stage 34.

[0123]

Also, according to the exposure apparatus of this embodiment, when the pattern on reticle R is printed onto wafer W1 (or W2), main control system 99 controls the stage system, more specifically, Y-axis linear motor 69, voice coil motors 71A to 71C, gas flow system 73 and the aforementioned wafer stage WST1 (or WST2), so that reticle R and wafer W1 (or W2) will transit in sequence from a state of acceleration to a state of synchronized constant velocity movement and to a state of deceleration in parallel in the Y-axis direction. For this reason, it is possible to print the pattern on reticle R onto wafer W1 (or W2) by a scanning exposure method. Here, in the stage system according to this embodiment, even

in the case where a reticle disposed on reticle fine stage 32 is driven at high acceleration via reticle coarse stage 34, it is possible to make voice coil motors compact and thereby making the entire stage system compact and lighter, making it possible to reduce the electrical power consumed by the linear motor. Therefore, it is reasonably possible to realize higher accelerations of the reticle coarse stage, making it possible to improve throughput by shortening a scanning exposure time. Also, by making the entire stage system compact, it is expected to improve the position controllability of a reticle, and as a result it is also expected to improve the exposure accuracy due to the improvement in positioning accuracy of a reticle and a wafer.

[0124]

In addition, in the embodiment above, it is explained about the case where the movable part of the gas flow system connected to reticle fine stage 32 is a plate shape member and the fixed part of the gas flow system connected to reticle coarse stage 34 is a pair of gas flowing mechanisms; however, for example, it is also possible to have the case where the movable part connected to reticle fine stage 32 is a gas jet mechanism blowing out a gas toward both sides in the Y-axis direction and the fixed part connected to reticle coarse stage 34 is a pair of plate shape members. Also in this case, it is possible to achieve the equivalent effect as in the embodiment above by performing the same control as the embodiment above.

[0125]

Also, in the embodiment above, it is specified that the first member is plate shape member 81, but this embodiment is not limited to this and it is also possible to construct the first member with part of reticle fine stage 32. In other words, it is also possible, for example, to change the shape of reticle coarse stage 34 from having a cross section that has the shape of a letter L to a letter U lying on its left side and install a gas jet mechanism such that gas can blow towards reticle fine stage 32 from the both sides in the Y-axis direction. Also, it is possible to have reticle coarse stage 34 in the shape of a rectangular frame enclosing reticle fine stage 32 and install a gas jet mechanism in the same way.

[0126]

<< Second Embodiment >>

Next, the second embodiment of the present invention is explained according to Figure 8 and Figure 9 (A) to Figure 9 (C). Here, the same codes are used for the same or equivalent components as those of the aforementioned first embodiment, and explanation of those components will be simplified or omitted.

[0127]

Compared to exposure apparatus 10 according to the aforementioned first embodiment, the exposure apparatus according to this second embodiment differs only in part of the structure of the stage system and the control method, and it is equivalent in terms of other structures and so forth. Therefore, explanation below is given with a central focus on these differences.

[0128]

This second embodiment is characterized wherein EI core system 73' is employed as a force generating system instead of gas flow system 73 used in the aforementioned first embodiment. Figure 8 is a perspective view showing a partial cross section of the aforementioned EI core system 73' placed between reticle fine stage 32 and reticle coarse stage 34.

[0129]

As evident from this Figure 8, EI core system 73' is equipped with electromagnetic unit 75A' fixed to reticle coarse stage 34 and magnetic unit 75B'. The magnetic unit 75B' is in reality fixed to the side surface on the -Y side of reticle fine stage 32 (see Figure 9 (A) and so forth).

[0130]

The aforementioned electromagnetic unit 75A' is equipped with hollow chassis 77' having the shape of a rectangular parallelepiped, and a pair of electromagnets 79A', 79B' as a second member each of which disposed on one and the other ends in the Y-axis direction, respectively, inside said chassis. Also, the aforementioned magnetic unit 75B' is equipped with iron plate 81' as a first member disposed between a pair of electromagnets 79A' and 79B', and arm member 83' having the shape of a letter U according to a plane view (when

viewed from the top) and fixed to the +Y side surface of said iron plate 81'. The arm member 83' is inserted into chassis 77' via opening 101' provided in chassis 77'.

[0131]

Because magnetic attraction force is generated between iron plate 81' constituting magnetic unit 75B' and electromagnets 79A', 79B' constituting electromagnetic unit 75A', if the magnetic attraction forces generated by electromagnets 79A' and 79B' are identical, for example, the force attracted toward the electromagnet on the closer side is applied to iron plate 81'.

[0132]

Here, the position (point of application of force) on reticle fine stage 32 to which the force by EI core system 73' is applied and the center of gravity of reticle fine stage 32 match in the X-axis direction as well as in the Z-axis direction. In other words, EI core system 73' is constructed to push the center of gravity of reticle fine stage 32, so a moment to rotate reticle fine stage 32 will not be generated at all by the force of EI core system 73'.

[0133]

Also, as in the first embodiment, in the case where voice coil motors 71B, 71C are in the state of neutrality, hardly any force in the Y-axis direction will be generated at EI core system 73', and when voice coil motors 71B, 71C shift from the state of neutrality either to the right or left, it is adapted to generate the force in the same direction as the shifted direction.

[0134]

Next, a drive control method of reticle stage RST of this embodiment including the operation of EI core system 73' is explained.

[0135]

Figure 9 (A) shows a condition where reticle coarse stage 34 is accelerated to the right (+Y side). As shown in this Figure 9 (A), when reticle coarse stage 34 is accelerated to the right, a current is supplied to voice coil motors 71B, 71C by main control system 99 (see Figure 5) in advance and reticle fine stage 32 is moved to the right that is opposite from the case in the first embodiment. In other words, at the time acceleration starts, reticle fine

stage 32 is set to the condition of Figure 9 (A) where it is positioned with a given offset by a determined amount on the +Y side in the Y-axis direction. If the acceleration of reticle coarse stage 34 starts in this condition, the reaction force to the left (-Y side) is applied to reticle fine stage 32; however, at the same time acceleration starts, the current is supplied to electromagnet 79B' on the right by main control system 99 and magnetic attraction force (force to the right) is applied to iron plate 81', and thereby iron plate 81' resisting the reaction force is held without having any contact, maintaining a predetermined gap by electromagnet 79B'. Because of this, it is made possible to move reticle fine stage 32 and reticle coarse stage 34 together in a uniformed manner, while ensuring a predetermined gap between iron plate 81' and electromagnet 79B' (i.e., between reticle coarse stage 34 and reticle fine stage 32).

[0136]

Here, the position of reticle fine stage 32 in the Y-axis direction is, as described above, measured by reticle Y-axis interferometers 66Y₁, 66Y₂, and so based on the values measured by these interferometers 66Y₁, 66Y₂ and the target value of reticle fine stage 32, main control system 99 changes the weighting of each force so as to gradually reduce the magnetic attraction force of electromagnet 79B' and to gradually increase the drive force of voice coil motors 71B, 71C, and thereby switching from electromagnet 79B' to voice coil motors 71B, 71C is smoothly performed as in the aforementioned first embodiment.

[0137]

And, during the synchronized constant velocity movement, as shown in Figure 9 (B), iron plate 81' is positioned almost in the state of neutrality, so it is adapted that main control system 99 controls reticle fine stage 32 to move in synchronization with the wafer stage with high response control by voice coil motors 71B, 71C. Also in this case, the reaction force does not act on reticle fine stage 32, so it is not necessary to make the force generated by the voice coil motors so large.

[0138]

Next, if reticle stage RST is decelerated from the state of Figure 9 (B), the reaction force acts on the right side of the paper surface (+Y side) that is opposite to the deceleration

direction; however, it is made possible to apply a magnetic attraction force toward the left side of the paper surface to iron plate 81' by supplying the current to electromagnet 79A'. Also in this case, it is made possible to perform the same control as in the first embodiment by controlling the current supplied to electromagnet 79A' based on the values measured by interferometers 66Y₁, 66Y₂, 66X and the control target value.

[0139]

As explained so far, according to this second embodiment, besides that it is possible to achieve the same effect as in the aforementioned first embodiment, a force to be generated is adjusted by controlling an amount of current supplied to the electromagnet constituting EI core system 73', so it is possible to improve the control performance of reticle fine stage 32 during acceleration and deceleration motions of reticle stage RST.

[0140]

In addition, in the second embodiment above, it is adapted such that the weighting of the force generated by the electromagnet and the force generated by voice coil motors is performed based on the outputs of reticle interferometers 66Y₁, 66Y₂, 66X and the control target value; however, the present invention is not limited to this and for example by installing a gap measuring sensor to measure the gap between reticle fine stage 32 and reticle coarse stage 34, it is also possible to perform the weighting of the force generated by the electromagnet and the force generated by the voice coil motors based on the output of said gap measuring sensor and the control target value. Also, it is possible to perform the weighting using both the outputs of the reticle interferometers as well as the output of the gap measuring sensor.

[0141]

In addition, in the second embodiment above, it is explained about the case of EI core system 73' wherein the movable part connected to reticle fine stage 32 is an iron plate and the fixed part connected to reticle coarse stage 34 is a pair of electromagnets; however, it is not limited to this and for example it is also possible to have the case that the movable part connected to reticle fine stage 32 is an electromagnet that generates a magnetic field on the both sides in the Y-axis direction, and the fixed part connected to reticle coarse stage 34 is a

pair of iron plates. Also in this case, it is possible to achieve the equivalent effect as in the second embodiment above by performing the same control as the embodiment above.

[0142]

Also, in the embodiment above, it is specified that the first member is a sheet of iron plate 81', but the present embodiment is not limited to this and it is also possible to specify that the first member is reticle fine stage 32 (and a magnetic member installed on the side wall on the both sides in the Y-axis direction of reticle fine stage 32). In other words, for example, it is also possible to change the shape of reticle coarse stage 34 from having a letter L to that of a letter U lying on its left side and place an electromagnet facing the side wall (magnetic member) on the both sides in the Y-axis direction of the reticle fine stage 32. Furthermore, it is also possible to specify that the first member is the electromagnet and install a pair of iron plates that are the second member in the manner that they sandwich the electromagnet.

[0143]

In addition, in each embodiment above, it is explained about the case where the stage system of the present invention is employed on the reticle stage side, but it is not limited to this and it is also possible to employ it on the substrate stage side. For example, for an exposure apparatus for liquid crystal display, there is a scan type exposure apparatus that prints the pattern on a mask onto a substrate with a 1:1 upright image via a projection optical unit by moving a mask stage and a plate stage at a constant velocity in the same direction; and for such apparatus it is possible to appropriately employ the stage system of the present invention not only on the mask stage side but also on the plate stage side. In addition to this, for a proximity type X-ray exposure apparatus and so forth, it is also possible to employ the stage system of the present invention on the substrate stage side.

[0144]

In addition, in each embodiment above, it is explained about the case where a force generating system is installed on a single holder type reticle stage that is capable of mounting one reticle as a reticle stage, but it is not limited to this and for example it is also possible to install a force generating system in the same way on a double holder type reticle stage that is capable of mounting two reticles.

[0145]

In addition, in each embodiment above, it is explained about the case where the voice coil motors are used as a second drive system that drives reticle fine stage 32 in micro motion; however, as the second drive system, for example, it is also possible to employ so-called EI core that is comprised of an iron plate connected to either one of the fine stage and the coarse stage and a pair of electromagnets connected to the other stage so as to sandwich said iron plate from the both sides in the drive direction.

[0146]

In addition, in each embodiment above, it is explained about a double stage type exposure apparatus that performs a simultaneous parallel process using two wafer stages; however, the scope of application of the present invention is not limited to this, so the present invention can be appropriately applied to a single wafer stage type exposure apparatus as well.

[0147]

As an application of the exposure apparatus, it is not limited to an exposure apparatus for manufacturing semiconductors, and for example it is possible to be widely applied to an exposure apparatus for liquid crystal display that prints the liquid crystal display device pattern onto an angular glass plate as well as an exposure apparatus for manufacturing thin-film magnetic heads, micromachines, DNA chips and so forth. Also, it is possible to apply the present invention not only to micro devices such as semiconductor devices but also to an exposure apparatus that prints a circuit pattern onto a glass substrate or silicon wafer in order to manufacture reticles or masks to be used in optical exposure apparatuses, EUV exposure apparatuses, X-ray exposure apparatuses, electron beam exposure apparatuses and so forth.

[0148]

Also, it is possible to use higher harmonic wherein an infrared or visible single-wavelength laser beam emitted from a DFB semiconductor laser or fiber laser is amplified by a fiber amplifier to which for example an erbium (or both an erbium and an ytterbium) is doped, and its wavelength is converted to be an ultraviolet radiation using a non-linear optical crystal. Also, as for the magnification of the projection optical unit, it is not limited to a reduction unit and either a 1X magnification or an enlargement unit may be used.

[0149]

Device Manufacturing Method

Next, a preferred embodiment of a device manufacturing method where the above-described exposure apparatus is used in the lithography process is explained.

[0150]

Fig. 10 shows a flowchart for an example of manufacturing a device (a semiconductor chip such as IC and LSI, liquid display panel, CCD, thin film magnetic head, micro machine, etc.). As shown in Fig. 10, first, in Step 201 (design step), functions and performance of a device are designed (for example, a circuitry of a semiconductor device is designed), and a pattern designing for realizing such functions is performed. Following that, in Step 202 (mask fabrication step), a mask whereon the designed circuit pattern is formed is fabricated. Meanwhile, in Step 203 (wafer manufacturing step), a wafer is manufactured using a material such as silicon.

[0151]

Next, in Step 204 (wafer process step), using a mask and wafer prepared in Step 201 through Step 203, a real circuit, etc. is formed on a wafer by a lithography technology, etc as will hereinafter be described. Next, in Step 205 (device assembly step), using a wafer processed in Step 204, a device assembly is performed. In this Step 205, a dicing process, bonding process as well as packaging process (chip mounting) etc. are included as necessary.

[0152]

Lastly, in Step 206 (inspection step), inspections of a device made in Step 205 such as motion check test and endurance test are performed. A device is complete after having gone through these processes, and will then be shipped.

[0153]

Fig. 11 shows an example of a detailed flowchart for the above-described Step 204 for a semiconductor device. In Fig. 11, in Step 211 (oxidation step), a wafer surface is oxidized. In Step 212 (CVD step), an insulating film is formed on the wafer surface. In Step 213 (electrode formation step), an electrode is formed on the wafer surface by vapor deposition. In Step 214 (ion implantation step), ion is implanted in the wafer. Each of the above Step 211 through Step 214 constitutes the front-end process of each step in the wafer process, and they are selected and performed in accordance with a process required for each step.

[0154]

In each step in the wafer process, once the above-described front-end process is completed, the back-end process is performed in the following manner. In this back-end process, first of all, in Step 215 (resist formation step), a photosensitive agent is applied on the wafer. Consequent to that in Step 216 (exposure step), a circuit pattern on a mask is printed onto a wafer by the above-explained lithography system (exposure apparatus) and exposure method. Next in Step 217 (development step), the exposed wafer is developed, and in Step 218 (etching step), the exposed members in the area other than where a resist is remaining is removed by etching. Next in Step 219 (resist removal step), a resist that is no longer necessary now that etching is done is removed.

[0155]

By repeating these front-end and back-end processes, multiple circuit patterns are formed on a wafer.

[0156]

If the device manufacturing method of the present embodiment as described above is used, the exposure apparatus of the above described embodiment can be used in the exposure process (Step 216), so exposure can be performed with a high throughput and good positioning accuracy between a reticle and wafer. Consequently, a productivity of a highly integrated micro device where fine patterns are formed can be improved.

[0157]

Effect of the Invention

As explained above, the stage system of the present invention has effects of reducing a weight increase due to higher acceleration and driving stage(s) efficiently.

[0158]

The exposure apparatus of the present invention has an effect of performing scanning exposure with a high throughput.

[0159]

The device manufacturing method of the present invention has an effect of improving the productivity of highly integrated micro devices where fine patterns are formed.

[Brief Explanation of Figures]

[Fig. 1]

It is a schematic partial cross sectional view of the exposure apparatus according to the first embodiment.

[Fig. 2]

It is a magnified view of the vicinity of the projection optical unit mounting member.

[Fig. 3]

It is a perspective view of the reticle stage and its vicinity.

[Fig. 4]

Fig. 4 (A) is a view for explaining the structure of a voice coil motor, and Fig. 4 (B) is a view for explaining the structure of a gas flow mechanism.

[Fig. 5]

It is a view showing a control unit of the exposure apparatus according to the first embodiment.

[Fig. 6]

Fig. 6 (A) through Fig. 6(C) are views for explaining the state of a voice coil motor as well as gas flow system when a reticle stage is moving and accelerated, moving in synchronization at a constant velocity, and is moving and decelerated.

[Fig. 7]

Fig. 7 (A) is a view showing changes in the acceleration of the reticle coarse stage, and Fig. 7 (B) is a view showing changes in the velocity of the reticle coarse stage.

[Fig. 8]

It is a perspective partial cross sectional view of the EI core system.

[Fig. 9]

Fig. 9 (A) through Fig. 9 (C) are views for explaining the state of a voice coil motor as well as EI core system when the reticle stage according to the second embodiment is moving and accelerated, moving in synchronization at a constant velocity, and is moving and decelerated.

[Fig. 10]

It is a flowchart for explaining the device manufacturing method according to the present invention.

[Fig. 11]

It is a flow chart showing a specific example of the step 204 in Fig. 10.

[Explanation of the Symbols]

- 10 exposure apparatus
- 32 reticle fine stage (second stage)
- 34 reticle coarse stage (first stage)
- 66Y₁, 66Y₂, 66X reticle interferometer (position measurement system)
- 69 Y axis linear motor (first drive system)
- 71A through 71C voice coil motor (second drive system)
- 73 gas flow system (force generating system)

73' EI core system (force generating system)
75A' electromagnetic unit
75B' magnetic unit
79A, 79B gas jet mechanism (second member)
79A', 79B' electromagnet (second member, a part of electromagnetic unit)
81 plate member (first member)
81' iron plate (first member, magnetic body)
99 main control system (drive control system, control system)
R reticle (mask, object)
W1, W2 wafer (substrate, object)
WST1, WST2 wafer stage (third stage)

[Fig. 5]

103 signal processing system
109 first displacement sensor
111 second displacement sensor
ALG1, ALG2 alignment unit
84 wafer X interferometer
80, 82 wafer Y interferometer
66X reticle X interferometer
66Y₁, 66Y₂ reticle Y interferometer
107 light source control system
105 blind drive system
16 first vibration isolation unit
24 second vibration isolation unit
102A, 102B Y axis position correction mechanism
69 Y axis linear motor
71A voice coil motor
71B voice coil motor
71C voice coil motor
73 gas flow system
70 wafer stage drive system

[Fig. 10]

201 design (function, performance, pattern)
202 mask fabrication
203 wafer manufacturing
204 wafer process
205 device assembly
206 inspection
shipment

[Fig. 11]

214 ion implantation

211 oxidation
212 CVD
213 electrode formation
215 resist formation
216 exposure
217 developing
218 etching
219 resist removal
front-end process
back-end process